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STRESS ANALYSIS OF G&C POWER CIRCUITS OF TORPEDO MK 46 MOD 5 (NEARTIP)

April 1977

Prepared for

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

Under Contract N00123-76-C-0797

ARINC RESEARCH CORPORATION

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SUMMARY

A worst-case stress analysis of power circuits of the guidance and control system of Torpedo Mk 46 Mod 5 (NEARTIP) was performed to determine any component application problems. Of the 328 components analyzed, 5 were found to be overstressed under normal system operating conditions, and 6 were overstressed during the short circuit protection mode of operation. Thirty-three components were found to exceed the derating guidelines of NAVSEA 0967-LP-597-1010.

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CONTENTS

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1
INTRODUCTION

ARINC Research Corporation is conducting worst-case stress analyses of selected circuits of Torpedo Mk 46 Mod 5 (NEARTIP) to ensure that the circuit components are not degrading system reliability. Component stresses, stress ratios, and other application factors are being considered.

This report, prepared for the Naval Ocean Systems Center under Contract N00123-76-C-0797, documents the analysis of the first group of circuits chosen for study: the control group electronics that supply power to the NEARTIP guidance and control (G&C) system. These circuits were selected for initial analysis since power circuits have historically been found to contain a higher percentage of components exceeding their recommended stress rates than in other electronic configurations.

Section 2 of this report discusses the ground rules for this analysis; Section 3 presents the results of the study; and Section 4 presents conclusions and recommendations. Detailed component stress data appear in Appendix A, and relevant Data Analysis Reports (DARs) prepared by ARINC Research are reproduced in Appendixes B and C.

2
ANALYSIS GROUND RULES

The following documentation, specifications, and ground rules applied to the stress analysis of NEARTIP G&C system components.

2.1 APPLICABLE DOCUMENTATION

Title	Number	Date or Revision
Parts Application and Reliability Information Manual for Navy Electronic Equipment	NAVSEA 0967-LP-597-1010	November 1975
Reliability Prediction of Electronic Parts	MIL-HDBK-217B	20 Sept. 1974
Capacitors, Selection and Use of	MIL-STD-198C	7 July 1975
NEARTIP Parts List	PL3235742	4 May 1976
NEARTIP Environmental Test Program	–	1
NEARTIP Component Tolerance Catalog	ARINC Research, W76-1640-TN01	August 1976
Schematic Power Supply A6	3235501	B

2.2 SPECIFICATIONS

- Ambient temperature = 70°C (maximum system specification)
- Input power from torpedo alternator:

  Voltage = 40 ± 5 Vdc

- Output power requirements:

Voltage, volts	Tolerance, ±volts	Max Load, ohms
+15	0.75	6
-15	0.75	15.3
+30	1.5	61
-30	1.5	61
+95	12	1M
22.5 (4.8 kHz)		
In phase	1.5 rms	83‖0.33 uf
Out phase	1.5 rms	1.1K
26 (400 Hz)	1.0 rms	130‖2.53 uf

2.3 COMPONENT VALUES

Nominal resistance values were used for all stress calculations, since variations due to tolerance would not significantly affect the results of the calculations. The worst-case value at 70°C was used for all other component parameters.

2.4 STRESS VALUES

Stress calculations were made for the parameters shown in Table 1. These parameters were extracted from NAVSEA 0967-LP-597-1010, Table B. As a minimum for each component type, those parameters applicable to MIL-HDBK-217B failure rate calculations were selected. The calculations established whether the device exceeds the recommended derating factor of Table 1, or whether the device rating was exceeded (overstressed).

NOSC directed that the above-referenced NAVSEA document be utilized to assure that parameters and derating guidelines used in this study were selected in a manner that could be supported by recognized naval documentation. This handbook was developed by the Naval Ship Engineering Center to instruct design and project engineers in the meaning of and guidelines for electrical and electronic part and device standardization, reliability and quality screening levels, design applications, derating, and electrical parameters affecting part and device reliability.

In some instances, the calculated stress values were greater than the actual levels, but unless a problem was noted the calculated value was used to facilitiate analysis.

TABLE 1. COMPONENT DERATING GUIDELINES FROM NAVSEA 0967-LP-597-1010 (Sheet 1 of 2)

Part Type	Derating Parameter	Derated Value, Pct.
Resistors		
Carbon composition	Power	50
Film, high stability	Power	40
Wirewound, accurate	Power	40
Wirewound, power	Power	40
Capacitors		
All	Ripple voltage	(Adhere to rating)
Ceramic	Voltage	50
Glass	Voltage	50
Mica	Voltage	60 dipped, 40 molded
Plastic	Voltage	50
Mylar	Voltage	60
Paper	Voltage	50
Tantalum, solid	Voltage	50
	Reverse voltage	2
	Circuit impedance	>3Ω/volt
Tantalum, wet	Voltage	60
	Reverse voltage	0
Tantalum, foil	Voltage	60
Magnetic devices*		
	Power	50
	Current density	2.0 mA/cir. mil
	Current (continuous)	60
	Current (surge)	90
	Voltage (continuous)	60
	Voltage (surge)	90
	Hot spot temperature (operating)	75

*Only those parameters consistent with the individual device specification will be calculated.

TABLE 1. (Sheet 2 of 2)

Part Type	Derating Parameter	Derated Value, Pct.
Transistors	Power	40
	Junction voltage (steady state)	75
SCRs	Junction temperature	100° C, max.
	Current (continuous)	60
Zener diodes	Current (continuous)	60
Signal diodes	Current (continuous)	60
	Power	50
Linear microcircuits	Junction temperature	100° C, max.
	Voltage (signal)	75
Digital microcircuits	Junction temperature	100° C, max
	Fanout	70 to 90
	Supply voltage	Hold to mfr. nom. ratings

A thermal resistance of 1.3° C/W case-to-ambient (Θ_{CA}) was assumed for heat-sunk transistors. Based on an evaluation of standard texts and the Bendix report, Heat Transfer Analysis, Mk 46 Torpedo NEARTIP Control Assembly, the stated value was derived as follows:

$$\begin{aligned}\Theta_{\text{case-ambient}} &= \Theta_{\text{case-heatsink}} + \Theta_{\text{heatsink-ambient}} \\ &= 0.3^\circ C/W + 1^\circ C/W \\ &= 1.3^\circ C/W.\end{aligned}$$

2.5 DEFINITIONS

The following definitions applied to this analysis:

a. Overstress – The condition in which a component exceeds any of its maximum parametric (P) ratings.

b. Recommended Derating Guidelines – The percentage of a component's maximum parametric rating that NAVSEA 0967-LP-597-1010 recommends not be exceeded, i.e.,

$$P_{stress}\ (\text{pct.}) = \frac{P_{actual}}{P_{rated}} \times 100\%.$$

For carbon resistors, P_{stress} (pct.) $\leq 50\%$.

c. Recommended Stress Ratio – The same as the Recommended Derating Guideline, except that it is expressed as a ratio:

$$P_{stress}\ (\text{ratio}) = \frac{P_{actual}}{P_{rated}}.$$

For carbon resistors, P_{stress} (ratio) ≤ 0.5.

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3
RESULTS OF ANALYSIS

3.1 GENERAL

A detailed worst-case stress analysis incorporating the ground rules presented in Section 2 was performed on NEARTIP guidance and control power circuitry (NAVORD Dwg. 3235501)*. The resultant stress data for all components are presented in Appendix A. The analysis indicated potential problems in the following assemblies:

a. +15V regulator A6A2

b. -15V regulator A6A4

c. ±30V regulator A6A3

d. Power output and oscillator A6A3, A6A1A1

e. Electronic component A6A1A1A3 (actuator controller)

f. 4.8 kHz oscillator A6A1A1A2

g. 400 Hz oscillator A6A1A1A1

Stress data for components of the above assemblies that were found to exceed their specified rating or recommended stress ratio are presented in Table 2.

3.2 LABORATORY AND SYSTEM MEASUREMENTS

System and board-level measurements were taken to verify circuit operation. The measurements that proved relevant to this analysis are briefly discussed below.

3.2.1 Ripple Voltage

Ripple voltage measurements were made on all tantalum capacitors in the G&C power circuits. These measured levels were utilized in calculating stress values.

*The analysis was not in fact purely worst-case, since nominal resistance values were used for all calculations and capacitor ripple was a measured value.

TABLE 2. COMPONENTS WITH POSSIBLE STRESS PROBLEMS IN NEARTIP G&C POWER CIRCUITS
(Sheet 1 of 6)

Part Number	Stress Ratio		Condition of Unit	Stress Parameter	NEARTIP History	Comments
	Existing	Recom.*				
A. +15 VOLT REGULATOR A6A2						
R3 (A1) RLR70	0.6	0.4	Steady state	Power	No reported failures	
R4 (A2) 2540940	0.83	0.4	Steady state	Power	Two previous failures	1. ARINC Research investigated possible device application problem; see DAR 77-008, App. B. 2. Calculated power is 1W.
R4 (A2) 2540940	12.5	0.4	Under short current protection	Power	Two previous failures	Calculated power is 15W.
U3 2540932	0.9	0.75	Steady state	Applied voltage	One reported failure	1. Failed device checked good when removed from system. 2. Factory states there is a 10V safety margin at 50V level. 100% of parts will operate at this level. If 60V is used as the maximum rating voltage, a stress ratio of 0.75 is obtained. 3. Measured applied voltage is 45V.

*Obtained from NAVSEA 0967-LP-547-1010.

TABLE 2. (Sheet 2 of 6)

Part Number	Stress Ratio		Condition of Unit	Stress Parameter	NEARTIP History	Comments
	Existing	Recom.*				
A. (Continued)						
C1 2540912-1	20 kHz	<10 kHz	Steady state	Operating frequency	No reported failures	Device has 20 mV voltage at 20 kHz measured at system level. It is rated at 111 mV at 10 kHz.
C1 2540912-1	0.6 V(rev)	0 V(rev)	W/sys. turn-on transient	Reverse voltage	No reported failures	ARINC Research investigated prob.; see DAR 77-009, App. C
L1 2557348	0.83	0.6	Steady state	Test current	No reported failures	1. Test current was used as device rating. 2. Calculated current is 2.5A.
L1 2557348	3.33	0.6	Under short circuit conditions	Test current	No reported failures	Calculated current is 10A.
B. -15 VOLT REGULATOR A6A4						
Q1 C03 2N2222A	0.65	0.4	Under short circuit conditions	Power	No reported failures	Calculated power is 224 mW.
Q16 A6A1A1 3235717	0.62	0.4	Steady state	Power	No reported failures	Calculated power is 29.3W.
Q16 A6A1A1 3235717	1.62	0.4	Under short circuit condition	Power	No reported failures	Calculated power is 76.5W.

TABLE 2. (Sheet 3 of 6)

Part Number	Stress Ratio		Condition of Unit	Stress Parameter	NEARTIP History	Comments
	Existing	Recom.*				
B. (Continued)						
R2 E02 RNC60H	0.61	0.4	Steady state	Power	No reported failures	Calculated power is 76 mW.
R4 B01 2540940	0.58	0.4	Over-current protection mode	Power	No reported failures	
R17 2540940	0.58	0.4	Over-current protection mode	Power	No reported failures	
C. POWER OUTPUT AND OSCILLATOR ASSEMBLY A6A3						
Q11 3235704	0.54	0.4	Test bench, dc steady state	Power	One reported failure	Open emitter to collector.
Q11 3235704	0.58	0.4	Steady state system conditions	Power		
Q12 2N3902	0.58	0.4	Test bench, dc steady state	Power	No reported failures	System conditions could not simulate this test.
R4 RER60	0.88	0.4	Steady state	Power	No reported failures	Calculated power is 3.7W.

TABLE 2. (Sheet 4 of 6)

Part Number	Stress Ratio		Condition of Unit	Stress Parameter	NEARTIP History	Comments
	Existing	Recom.*				
C. (Continued)						
R5 RER70	0.46	0.4	Steady state	Power	No reported failures	
R9 A03 RLR20	0.82	0.4	Steady state	Power	No reported failures	Calculated power is 3.36W.
R11 A03 RLR32	0.53	0.4	Steady state	Power	No reported failures	
VR 1 B03 2090168	0.61	0.5	Steady state	Power	No reported failures	
CR1 B03 1N914	0.84	0.6	Steady state	Current	No reported failures	Calculated current is 44 mA.
D. ±30 VOLT REGULATOR A6A3						
Q5 B03 2N2905A	0.55	0.4	Under short circuit conditions	Power	No reported failures	
Q6 B02 2N2222	0.65	0.4	Under short circuit conditions	Power	No reported failures	Calculated power is 226 mW.
Q14 3235704	1.48	0.4	Under short circuit conditions	Power	No reported failures	Calculated power is 71W.

TABLE 2. (Sheet 5 of 6)

Part Number	Stress Ratio Existing	Stress Ratio Recom.*	Condition of Unit	Stress Parameter	NEARTIP History	Comments
D. (Continued)						
Q15 3235717	1.19	0.4	Under short circuit conditions	Power	No reported failures	Calculated power is 57W.
R21 B03 RWR89	0.42	0.4	Steady state	Power	No reported failures	
R23 B02 RWR89	0.42	0.4	Steady state	Power	No reported failures	
R24 B03 RNC65H	0.73	0.4	Steady state	Power	No reported failures	Calculated power is 182 mW.
R27 B03 RNC60H	0.56	0.4	Steady state	Power	No reported failures	
R29 B02 RNC65H	0.73	0.4	Steady state	Power	No reported failures	Calculated power is 182 mW.
R30 A03 25409402	1.35	0.4	Under short circuit conditions	Power	No reported failures	Calculated power is 2.69W.
R33 A03 25409402	0.86	0.4	Under short circuit conditions	Power	No reported failures	Calculated power is 1.72W.
R35 B02 RNC60H	0.56	0.4	Steady state	Power	No reported failures	
C6 A02 M39006/9	0.63	0.6	Steady state	Voltage	No reported failures	

TABLE 2. (Sheet 6 of 6)

Part Number	Stress Ratio		Condition of Unit	Stress Parameter	NEARTIP History	Comments
	Existing	Recom.*				
E. ELECTRONIC COMPONENT ASSEMBLY A6A1A1A3						
R1 RWR89	0.5	0.4	Steady state	Power	No reported failures	
R2 RWR89	0.5	0.4	Steady state	Power	No reported failures	
R3 RWR89	0.5	0.4	Steady state	Power	No reported failures	
F. 4.8 KHZ OSCILLATOR A6A1A1A2						
C9 M39001/1	4.83	1	Steady state	Ripple voltage	No reported failures	Measured ripple is 580 mV(rms) at system level.
C10 M39001/1	4.83	1	Steady state	Ripple voltage	No reported failures	Measured ripple is 580 mV(rms) at system level.
G. 400 HZ OSCILLATOR A6A1A1A1						
C10/C11 M39006/1	1.13	1	Steady state	Ripple voltage	No reported failures	Measured ripple is 2.9 V(rms) at system level.

3.2.2 Reverse Voltage, +15V C1 (2540912-1)

A study was made to determine the effect of a 0.6-volt reverse voltage measured across this capacitor at turn-on. This device is a solid, sintered slug, tantalum capacitor that is not permitted (by specification) to have a reverse voltage. From laboratory measurements and discussions with the manufacturer, it was determined that a small amount of reverse voltage will, over a period of time, cause the capacitor to act as a forward-biased diode. It should be noted that this negative voltage is only present at the system test level for approximately 50 milliseconds at turn-on. No attempt was made to calculate the time that would be required for the capacitor to suffer damage from this limited exposure. There have been no reported failures of this device to date.

3.2.3 High Current, +15V R4 (A2, 2540940-1)

Laboratory measurements were made to determine what effect exposure to high current levels would have on this device. It was determined that the end solder terminations of the resistor melted under a current of approximately 7 amperes in a period of 4 minutes, and the resistor burned open at a current of 8.5 amperes in 20 minutes. Details of this evaluation appear in DAR 77-008, reproduced in Appendix B.

3.3 STRESSES DURING SHORT CIRCUIT CONDITION

If a component is stressed beyond its recommended stress level during a short-circuit mode of operation, a decision must be made concerning the ramifications of such an occurrence. Six components in NEARTIP G&C power circuits were found to be overstressed, and six others exceeded recommended stress levels when exposed to a short-circuit condition.

A shorted condition, leading to overstressed components and possible subsequent degrading of system reliability, can occur during both operations and testing. Under operational conditions, the failure may be intermittent or continuous, and the resultant component stress will be correspondingly intermittent or continuous. When the ±30- or ±15-volt power supplies are bench-tested, one of the tests is a short-circuit condition. This condition is intermittent, since the circuit output is shorted by activation of a spring-loaded switch.

It is evident that some G&C power circuit components are being overstressed. However, since these overstress conditions only occur during special testing or when a system failure has already occurred, it is believed that for all but one component they should be considered a secondary failure mechanism. The exception is +15V R4 (A2). Because of the very high current level that can exist in this regulator, as discussed in Section 3.2.3, this component is a candidate for change.

3.4 NEARTIP COMPONENT FAILURE HISTORY

A survey was made of data on all NEARTIP component failures to date to determine if any of the devices identified in this study as exhibiting possible stress problems also have a history of operational failure. Three of the devices were observed to fall into this category:

a. +15V regulator A6A2 - R4 (A2), 25409040-1. Two operational failures have been reported. In both instances the resistors were found to have fused open due to excessive current.

b. +15V regulator A6A2 - U3, 2540932. One operational failure has been reported. The device subsequently tested good.

c. Power output A6A3 - Q11, 3235704. A failure occurred during special exploder testing. The device was found to have an open emitter-to-collector junction.

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4
CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were derived from this analysis.

4.1 CONCLUSIONS

Of the 328 components analyzed, 44 were found to have possible stress problems (see Table 2). Of the stressed components:

a. Five were overstressed under steady-state operating conditions.

b. Six were overstressed during the short-circuit protection mode of operation.

c. Thirty-three exceeded the recommended derating guidelines of NAVSEA 0967-LP-597-1010 – 25 during steady-state operation and 6 during short-circuit protection conditions.

4.2 RECOMMENDATIONS

Based on this study, ARINC Research recommends:

a. That C1 (+15 volt regulator A6A2) be replaced, or the reverse voltage present at turn-on be eliminated. This matter is addressed in ARINC Research DAR 77-009, reproduced in Appendix C.

b. That any testing of short-circuit protection be held to a minimum, since certain components of the NEARTIP circuitry exhibit stress problems during short-circuit conditions. It is not felt that action is necessary to change these components, since the noted problem is a secondary-failure mechanism.

c. That R4 (+15 volt regulator A6A2) undergo further analysis. An attempt should be made to lower the power levels during normal and short-circuit operation. Further details on this subject are presented in DAR 77-008 (See Appendix B).

d. That a study be made to determine if a different size or type of device could be substituted for C9, C10 (4.8 kHz oscillator A6A1A1A2) and C10, C11 (400 Hz oscillator A6A1A1A1), which were found to have excessive ripple voltage.

e. That inductor specifications include a maximum current rating. (Bendix has been assigned this task as an action item by NOSC.) If it is determined that the presently specified test current is the maximum rated value, it is then recommended that L1 (+15V regulator A6A2) be evaluated in terms of the best manner in which its stress ratio can be lowered.

f. That CR1B03 (power output and oscillator A6A3) be a type 1N645 rather than the 1N914 presently specified. Circuit stresses for the 1N645 will be within recommended ratings.

g. That the transistors and resistors that have a power stress ratio greather than 0.6 under steady-state operating conditions, as identified in Table 2, be evaluated to determine the most cost-effective method of lowering this ratio to a maximum of 0.6; and, if practical, to 0.4. (It was not felt that the power stresses found to fall between 0.4 and 0.6 are significant enough to warrant further action.)

APPENDIX A

COMPONENT STRESS DATA

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TABLE 1 . SEMICONDUCTOR STRESS - TRANSISTORS   Date ________

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q1	TX2N5038	70	52,000	1910.0 7280.0	.1(3) .27(1) .14	90	45	.5	$V_X = V_{CE}$
Q1 (A1)	TX2N2905A	70	450	15.0 29.0	.1 .1(1)	60	45	.75	$V_X = V_{CE}$
Q1 (A2)	TX2N2222A	70	350	1.75(2)	.1	75	1.6	.1	$V_X = V_{CB}$
Q2 (A2)	TX2N2905A	70	450	17(2)	.1	60	15.75	.26	$V_X = V_{CB}$
Q3 (A2)	TX2N2222A	70	350	1.41	.1	75	16.32	.22	$V_X = V_{CB}$
Q4 (A2)	TX2N5116	70	370	1.0	.1	30	16.32	.54	$V_X = V_{GS}$
Q5 (A2)	TX2N2905A	70	450	14.3	.1	60	45	.75	$V_X = V_{CB}$

(1) Under Short Circuit Conditions
(2) Under Over Voltage Protection Conditions
(3) All Stress Ratios Less Than .1 Are Rounded Off to .1.

(Sheet 1 of 8)

TABLE 1. SEMICONDUCTOR STRESS

Date ______

Unit +15 V Regulator, A6A2, 3235501

Ref. Des.	Type	T_A (°C)	T_{JR} (°C)	T_{JA} (°C)	T_{JA}/T_{JR}	I_{FR} (amps)	I_{FA} (amps)	I_A/I_R	Notes
Q2(SCR)	2540943	70				16	3	.19	

(Sheet 2 of 8)

TABLE 1. RESISTOR STRESS

Date ______

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R1(A1)	RNC60H	32.4K	1	70	125	~ 0	.1	
R1(A2)	RLR20	3K	2	70	500	86	.17	
R2(A1)	RLR20	33K	2	70	500	~ 0	.1	
R2(A2)	RLR20	5.1K	2	70	500	1	.1	
R3(A1)	RLR20	5.1K	2	70	500	300	.6	
R3(A2)	RLR20	510	2	70	500	32	.1	
R4(A1)	RLR20	68	2	70	500	43	.1	
R4(A2)	254094	.15	3	70	1200 1200	1000 15W	.83 12.5	(1,3) (2,4)
R5(A1)	RLR20	3.3K	2	70	500	1	.1	
R5(A2)	RLR20	300	2	70	500	9	.1	
R6(A1)	RLR20	33	2	70	500	3.7	.1	
R6(A2)	RLR20	5.1K	2	70	500	1	.1	
R7(A1)	RNC60H	2.49K	1	70	125	18	.1	
R7(A2)	RNC60H	26.1K	1	70	125	3.2	.1	

(1) Under Steady State Conditions
(2) Under Short Circuit Conditions
(3) Exceeds Recommended Maximum Stress Ratio of .4
(4) Device is Overstressed

(Sheet 3 of 8)

TABLE 1. RESISTOR STRESS Date ________

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R8 (A2)	RNC60	75.0K	1	70	125	1.1	.1	
R9 (A2)	RLR20	5.1K	2	70	500	100	.2	
R10(A2)	RLR20	1K	2	70	500	2	.1	
R11(A2)	RLR20	10K	2	70	500	20	.1	
R12(A2)	RWR89	1.47K	1	70	2460	560	.23	
R13(A2)	RLR20	110	2	70	500	3.0	.1	
R14(A2)	RLR20	220	2	70	500	~ 0	.1	
R15(A2)	RCR20	2.2M	5	70	250	~ 0	.1	
R16(A2)	RLR20	91	2	70	500	100	.2	
R17(A2)	RLR20	330	2	70	500	33	.1	
R1	RER60	0.301	1	70	4200	3000	.71	Used During Over Voltage Protection

(Sheet 4 of 8)

TABLE 1 . CAPACITOR STRESS

Date ____________

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C1	2540912-1	70	30	15.75	.53	Tantalum - Nonsolid (Polarized sintered slug) - $V_{REVERSE}$ = 0.6V(2)
		70	110 mV RMS	22 mV VRMS	.21(1)	V_{RIPPLE}
C1 (A1)	M23269	70	500	6.64	.1	Glass
C1(A2)	M39014	70	100	15.75	.16	Ceramic
C2 (A1)	M39014	70	100	6.64	.1	Ceramic
C2 (A2)	M39014	70	50	3.54	.1	Ceramic
C3 (A1)	M39006/9	70	75	45	.6	Tantalum - Nonsolid (Polarized)
C4 (A1)	M39014	70	100	45	.45	Ceramic
C5 (A1)	M39014	70	100	45	.45	Ceramic
C6 (A1)	M39014	70	100	45	.45	Ceramic

(1) V_{Rated} ripple is for 10KHz, operation at >10KHz is not recommended per MIL-STD-198C.
(2) No $V_{Reverse}$ is allowed for sintered slug capacitors (MIL-STD-198C).

(Sheet 5 of 8)

TABLE 1 . SEMICONDUCTOR STRESS - DIODES

Date ______

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR1 (A1)	TX1N753A	70	120	336	.28	18	50	.36	$I = I_Z$ Cont.
VR1 (A2)	TX1N4469	70	318	1050	.3	19.5	67	.29	$I = I_Z$ Cont.
VR2 (A1)	TX1N753A	70	2.7	336	.1	1.0	50	.1	$I = I_Z$ Cont.
CR1	TX1N3890	70	NA	--	NA	1800 7000	12000 12000	.15 .59	$I = I_O$ Cont. $I = I_O$ Short Ckt
CR1 (A2)	TX1N5417	70	~0	3740	.1	~0	2600	.1	$I = I_O$ Cont.
CR2 (A2)	TX1N3600	70	7.2	140	.1	11	140	.1	$I = I_O$ Cont.
CR3 (A2)	TX1N5417	70	NA	--	NA	~0	2600	.1	$I = I_O$ Cont.
CR4 (A2)	TX1N3600	70	22	140	.16	33	140	.24	$I = I_O$ Cont.
CR5 (A2)	TX1N3600	70	22	140	.16	33	140	.24	$I = I_O$ Cont.

(Sheet 6 of 8)

TABLE 1. MAGNETIC STRESS

Date ____________

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	P_{rated} (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	V_{rated} (volts)	V_{actual} (volts)	$\frac{V_{actual}}{V_{rated}}$	I_{rated} (mA)	$T_A = 70°C$ I_{actual} (mA)	$T_A = 70°C$ $\frac{I_{actual}}{I_{rated}}$
L1	2557348					--	--	3000	2500	.83(1)
						--	--	3000	10,000	3.33 (2)

(1) Under Steady State Conditions the Device Exceeds Recommended Ratio of .6
(2) Under Short Circuit Conditions the Device is Overstressed

(Sheet 7 of 8)

TABLE 1 . INTEGRATED CIRCUIT STRESS   Date

Unit +15V Regulator, A6A2, 3235501

Ref. Des.	Type	T_A (°C)	T_{JR} (°C)	T_{JA} (°C)	$\frac{T_{JA}}{T_{JR}}$	V_{PSR} (volts)	V_{PSA} (volts)	$\frac{V_{PSA}}{V_{PSR}}$	V_{inR} (volts)	V_{inA} (volts)	$\frac{V_{inA}}{V_{inR}}$	I_{LR} (mA)	I_{LA} (mA)	$\frac{I_{LA}}{I_{LR}}$	Notes
U1	3235747	70	175	70	.4	16.5	6.64	.4	NA	--	NA		4-CMOS	OK	4001
U2	3235750	70	175	70	.4	16.5	6.64	.4	NA	--	NA		2-CMOS	OK	4013
U3	2540932	70	150	75	.5	NA	--	NA	50	45	.9(1)	NA	--	NA	LM105

(1) Exceeds recommended voltage stress level of 0.75
Factory states that there is ≈ a 10 volt safety margin in the 50V level and 100% of parts will operate at this level. If 60V is used as a rating an acceptable stress ratio of .75 is obtained.

(Sheet 8 of 8)

TABLE 2 . SEMICONDUCTOR STRESS - TRANSISTORS Date ____________

Unit -15V Regulator, A6A4, 3235501

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q1C03	TX2N2222A	70	350	123 224(2)	.35 .65(1)	75 --	38 --	.51 --	$V_X = V_{CB}$
Q2C02	TX2N2905A	70	450	49	.12	60	8	.1	$V_X = V_{CB}$
Q3E01	TX2N2905A	70	450	27	.1	60	5	.1	$V_X = V_{CE}$
Q4C03	TX2N2905A	70	450	21	.1	60	21	.35	$V_X = V_{CE}$
Q5E03	TX2N4858	70	250	2.3	.1	40	16.32	.41	$V_X = V_{DS}$
Q6G04	TX2N2905A	70	450	16	.1	60	16	.27	$V_X = V_{CE}$
Q16 (A6A1A1)	3235717	70	47W 47W	29.33W 76.5 W	.62(1) 1.62(2,3)	100 --	29 --	.29 --	$V_X = V_{CE}$

(1) Exceeds Recommended Maximum Power (Temperature) Stress Ratio of 0.4
(2) Event Occurs During a Short Circuit Condition
(3) Device is Overstressed

(Sheet 1 of 6)

TABLE 2. SEMICONDUCTOR STRESS - SCR

Date ______

Unit -15V Regulator, A6A4, 3235501

Ref. Des.	Type	T_A (°C)	T_{JR} (°C)	T_{JA} (°C)	T_{JA}/T_{JR}	I_{FR}	I_{FA}	I_A/I_R	Notes
Q17	250943	70				16A	1.75A	.12	

(Sheet 2 of 6)

TABLE 2. RESISTOR STRESS

Date ____________

Unit -15V Regulator, A6A4, 3235501 Rev. B

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R1C04	RWR89	1.82K	1	70	2460	810	.33	
R2E02	RNC60H	2.21K	1	70	125	76	.61	(1)
R3C01	RLR07	100	2	70	250	2	.1	
R4B01	2540940	1.5	3	70	2000 2000	400 1150	.2 .58	 (1, 2)
R5E02	RNC60H	340	1	70	125	26	.21	
R6E02	RNC60H	4.75K	1	70	125	35	.28	
R6 (A6A1A1)	RER60F	0.301	1	70	4200 21000	~0 920	.1 .1	$P_{Steady\ State}$ (2)
R7C01	RLR07	1.1K	2	70	250	22	.1	
R8D03	RLR07	1K	2	70	250	2	.1	
R9F03	RLR07	10K	2	70	250	25	.1	
R10E03	RWR89	1.47K	1	70	2460	560	.23	
R11G04	RCR20	2.2M	5	70	250	1	.1	

(1) Exceeds Recommended Maximum Power Stress Ratio of 0.4
(2) Event Occurs During a Short Circuit Condition

(Sheet 3 of 6)

TABLE 2. RESISTOR STRESS

Date ______

Unit -15V Regulator, A6A4, 3235501

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R11 (A6A1A1A3)	RLR07	330	2	70	250	8	.1	
R12E04	RLR07	510	2	70	250	72	.29	
R13E04	RLR20	820	2	70	500	115	.23	
R14F04	RLR07	510	2	70	250	1	.1	
R15F04	RLR07	91	2	70	250	60	.24	(3)
R16C03	RLR07	1K	2	70	250	60	.24	
R17B01	2540940	1.5	3	70	2000 2000	400 1150	.2 .58	 (1, 2)

(1) Exceeds Recommended Maximum Power Stress Ratio of 0.4
(2) Event Occurs During a Short Circuit Condition
(3) Assumes 50% Duty Cycle in Over Voltage Condition

(Sheet 4 of 6)

TABLE 2. CAPACITOR STRESS

Date ______

Unit -15V Regulator, A6A4, 3235501

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C3E03	M39006/9	70	75	45	.6	Tantalum-Nonsolid (Polarized sintered slug)
C4C02	M39014	70	200	13	.1	Ceramic
C5C02	M39014	70	100	4	.1	Ceramic
C6E03	M39014	70	50	13	.26	Ceramic
C7E04	M23269	70	500	6	.1	Glass
C8F04	M39006/9	70	50	16	.32	Nonsolid Tantalum

(Sheet 5 of 6)

TABLE 2. SEMICONDUCTOR STRESS - DIODES Date

Unit -15V Regulator, A6A4, 3235501

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR1C04	Tx1N573A	70	140	336	.42	21	50	.42	$I = I_Z$ Cont.
VR2C02	TX1N941B	70	112.8	350	.32	9.14	32	.29	$I = I_Z$ Cont.
VR3G02	TX1N4469	70	318	1050	.3	19.5	67	.29	$I = I_Z$ Cont.
VR4G04	TX1N753A	70	18	336	.1	2.7	50	.1	$I = I_Z$ Cont.
CR1C02	TX1N914	70	1.3	175	.1	1.3	52.5	.1	$I = I_{AVG}$
CR2D01	TX1N3600	70	9	140	.1	9	140	.1	$I = I_O$ Cont.
CR3G03	TX1N5417	70	NA	--	NA	~0	2600	.1	$I = I_O$ Cont.
						2590	8000	.32	$I = I_{Surge}$

(Sheet 6 of 6)

TABLE 3. SEMICONDUCTOR STRESS - TRANSISTORS

Date ____________

Unit ±30V Regulators, A6A3, 3235501

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q5B03	TX2N2905A	70	450	34.2	.1	60	44	.73	$V_X = V_{CB}$
				248(2)	.55(1)	--	--	--	
Q6B02	TX2N2222A	70	350	40	.12	75	44	.59	$V_X = V_{CB}$
				226(2)	.65(1)	--	--	--	
Q7B03	TX2N2222A	70	350	89	.25	75	45	.61	$V_X = V_{CB}$
Q8B02	TX2N2905A	70	450	82	.18	60	45	.75	$V_X = V_{CB}$
Q9A03	TX2N2222A	70	350	4	.1	40	25	.63	$V_X = V_{CE}$
Q10A02	TX2N2905A	70	450	4	.1	60	25	.42	$V_X = V_{CE}$
Q14	3235704	70	48W	10W	.21	100	45	.45	$V_X = V_{CE}$
				71W	1.48(2,3)	--	--	--	
Q15	3235717	70	48	10W	.21	100	45	.45	$V_X = V_{CE}$
				57W	1.19(2,3)	--	--	--	

(1) Exceeds Recommended Maximum Power Stress Ratio of 0.4
(2) Under Short Circuit Conditions
(3) Device is Overstressed

(Sheet 1 of 5)

TABLE 3. RESISTOR STRESS Date ______

Unit ± 30V Regulators, A6A3, 3235501

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R20B03	RLR07	430	2	70	250	9.5	.1	
R21B03	RWR89	1.82K	1	70	2460	1042	.42	(1)
R22B02	RLR07	430	2	70	250	9.5	.1	
R23B02	RWR89	1.82K	1	70	2460	1042	.42	(1)
R24B03	RNC65H	3.84K	1	70	250	182	.73	(1)
R25A02	RLR07	2.2K	2	70	250	39	.16	
R26A03	RLR07	220	2	70	250	1.22	.1	
R27B03	RNC60H	9.31K	1	70	125	70	.56	(1)
R28A03	RLR07	220	2	70	250	1.22	.1	
R29B02	RNC65H	3.48K	1	70	250	182	.73	(1)
R30A03	2540940-2	1.0	1	70	2000 2000	520 2690	.26 1.35	(2)
R31A03	RNC65H	619	1	70	250	64	.26	
R32A03	RLR07	2.2K	2	70	250	39	.16	

(1) Exceeds Recommended Stress Ratio of 0.4
(2) Under Short Circuit Condition Component is Overstressed

(Sheet 2 of 5)

TABLE 3. RESISTOR STRESS

Date ______

Unit ±30V Regulators, A6A3, 3235501

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R33A03	2540940-2	1.0	3	70	2000	520	.26	
					2000	1720	.86	(1,2)
R34A02	RNC65H	619	1	70	250	64	.26	
R35B02	RNC60H	9.31K	1	70	125	70	.56	(1)

(1) Exceeds Recommended Stress Ratio of 0.4
(2) Under Short Circuit Conditions

(Sheet 3 of 5)

TABLE 3. CAPACITOR STRESS

Date ______

Unit ±30V Regulators, A6A3, 3235501

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C3A02	M39006/1	70	75	45	.6	Tantalum (Nonsolid) Polarized Etched Foil
C6A02	M39006/9	70	50	31.5	.63(1)	Tantalum
C7B03	M39014	70	200	8.2	.1	Ceramic
C8B02	M39014	70	200	8.2	.1	Ceramic
C9A03	M39014	70	100	6.3	.1	Ceramic
C20A02	M39014	70	100	6.3	.1	Ceramic
C11A03	M39006/9	70	50	31.5	.63(1)	Tantalum
C12B02	M39006/1	70	75	45	.6	Tantalum
C13A02	M39006/1	70	75	45	.6	Tantalum
C14A02	M39006/1	70	75	45	.6	Tantalum

(1) Exceeds Recommended Maximum Stress Ratio of 0.6

(Sheet 4 of 5)

TABLE 3. SEMICONDUCTOR STRESS Date ______

Unit ±30V Regulators, A6A3, 3235501

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR6B03	TX1N746A	70	79	336	.24	22.8	50	.46	
VR7B02	TX1N746A	70	79	336	.24	22.8	50	.46	
VR8A03	TX1N941B	70	135	350	.39	10.7	32	.33	
VR9A03	TX1N9418	70	135	350	.39	4.2	32	.13	
VR10A02	TX1N941B	70	135	350	.39	4.2	32	.13	
VR11A02	TX1N941B	70	135	350	.39	4.2	32	.13	
CR4B03	TX1N914	70	4.7	175	.1	4.7	52.5	.1	
CR5B02	TX1N914	70	4.7	175	.1	4.7	52.5	.1	
CR7A03	TX1N3600	70	4.9	140	.1	6.6	140	.1	
CR8A02	TX1N3600	70	4.9	140	.1	6.6	140	.1	

(Sheet 5 of 5)

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TABLE 4. RESISTOR STRESS Date ____________

Unit Electronic Component Assembly, A6A1A1A3

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R1	RWR89	1000	2	70	2460	1230	.5	(1)
R2	RWR89	1000	2	70	2460	1230	.5	(1)
R3	RWR89	1000	2	70	2460	1230	.5	(1)
R4	RLR20	300	3	70	500	26.1	.1	
R5	RLR20	300	3	70	500	26.1	.1	
R6	RLR20	300	3	70	500	26.1	.1	
R7	RLR20	300	3	70	500	26.1	.1	
R8	RLR20	300	3	70	500	26.1	.1	
R9	RLR20	300	3	70	500	26.1	.1	

(1) Exceeds Recommended Stress Ratio of .4

(Sheet 1 of 2)

TABLE 4. SEMICONDUCTOR STRESS - DIODES

Date ______________

Unit Electronic Component Assembly A6A1A1A3

Ref. Des.	Type	T_A (°C)	ACTUAL V_R	RATED V_R	V_A/V_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
CR1	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR2	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR3	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR4	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR5	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR6	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR7	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR8	TX1N5417	70	90	200	.45	~ 0	2500	.1	
CR9	TX1N5417	70	90	200	.45	~ 0	2500	.1	

(Sheet 2 of 2)

TABLE 5 . SEMICONDUCTOR STRESS   Date ______________

Unit Power Output & OSC Part of A6A3

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q1A03	TX2N3019	70	590	10	.1	80	45	.56	$V_X = V_{CE}$
Q2A03	TX2N3019	70	590	18	.1	80	45	.56	$V_X = V_{CE}$
Q3B02	TX2N2905A	70	450	10	.1	60	45	.75	$V_X = V_{CE}$
Q4B02	TX2N5116	70	370	.65	.1	30	1	.1	$V_X = V_{DS}$
Q11	3235704	70	48W	26W 28W	.54(1) .58(2)	100 --	45 --	.45 --	$V_X = V_{CE}$
Q12	TX2N3902	70	38.5W	22.5W	.58(1)	400	90	.23	$V_X = V_{CE}$
Q1	3235717	70	47.3W	6W	.1	100	45	.45	$V_X = V_{CE}$
Q2	3235717	70	47.3W	6W	.1	100	45	.45	$V_X = V_{CE}$
Q3	3235717	70	47.3W	6W	.1	100	45	.45	$V_X = V_{CE}$
Q4	3235704	70	47.3W	6W	.1	100	45	.45	$V_X = V_{CE}$
Q5	3235704	70	47.3W	6W	.1	100	45	.45	$V_X = V_{CE}$
Q6	3235704	70	47.3W	6W	.1	100	45	.45	$V_X = V_{CE}$

(1) Exceeds Recommended Power Stress Rating of .4 Under Test Bench Condition
(2) Exceeds Recommended Power Stress Rating of .4 Under Steady State Operating Conditions

(Sheet 1 of 8)

TABLE 5. SEMICONDUCTOR STRESS - Date ______

Unit Power Output OSC Part of A6A3

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
Q13	2N1774A SCR	70				1250	4000	.32	

(Sheet 2 of 8)

TABLE 5. RESISTOR STRESS

Date ______

Unit Power Output & OSC Part of A6A3

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	P_{actual}/P_{rated}	Notes
R1B03	RLR07	470	2	70	250	2.1	.1	
R2A03	RLR20	200	2	70	500	20	.1	
R3B03	RLR32	5.1K	2	70	1000	397	.4	
R4A03	RLR20	220	2	70	500	66	.1	
R5	RER70	1K	1	70	16800	7700	.46(1)	
R5A03	RTR12	200	5	70	750	18	.1	
R6A03	RLR20	750	2	70	500	66	.1	Nominal Resistance
R7A03	RLR20	10K	2	70	500 1250	~0 580	.1 .46(2)	Steady State Short Time Overload
R8A03	RLR20	3K	2	70	500	1.8	.1	
R9A03	RWR74	536	1	70	4100	3360	.82(1)	
R10A03	RWR89	267	1	70	2460	830	.34	
R11A03	RLR32	3.6K	2	70	1000	529	.53(1)	
R12	N/A							

(1) Exceeds Recommended Stress Ratio of 0.4
(2) Because of Short Time Constant Not Significant

(Sheet 3 of 8)

TABLE 5. RESISTOR STRESS

Date ______

Unit Power Output & OSC Part of A6A3

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R13B02	RLR20	560K	2	70	500	~0	.1	
R14B02	RLR07	100K	2	70	250	~0	.1	
R15B02	RWR89	909	1	70	2460	753	.31	
R16B02	RLR07	27K	2	70	250	70.9	.28	
R10	RLR07	1K	2	70	250	4	.1	
R1	RER60	1500	1	70	4200	1600	.38	
R2	RER60	1500	1	70	4200	1600	.38	
R3	RER60	1500	1	70	4200	1600	.38	
R4	RER60	1500	1	70	4200	3700	.88	(1)

(1) Exceeds Recommended Stress Ratio of .4

(Sheet 4 of 8)

TABLE 5 . CAPACITOR STRESS

Date ____________

Unit Power Output & OSC Part of A6A3

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C1A03	M39014/1	70	200	45	.23	Ceramic
C2B03	M39006/4	70	150	90	.6	Tantalum (Nonpol.,Plain Foil)
C3A02	M39006/1	70	75	45	.6	Tantalum (Pol., Etched Foil)
C4B02	M39014/2	70	200	60	.3	Ceramic
C5B02	M39014/2	70	200	45	.25	Ceramic

(Sheet 5 of 8)

TABLE 5 . SEMICONDUCTOR STRESS - DIODES Date ____________

Unit Power Output & OSC Part of A6A3

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR1B03	2090168	70	430	700	.61 (1)	10	21	.48	
VR2B03	TXIN3025B	70	142	700	.2	--	N/A	--	
VR3B03	TXIN3026B	70	161	700	.23	--	N/A	--	
CR1B03	TXIN914	70	44	175	.25	44	52.5	.84 (2)	$I_R = I_{SS}$
CR2B02	TXIN3600	70	15	140	.11	22	140	.16	
CR5	TXIN1202A	70	--	N/A	--	46	12000	.1	
CR6	TXIN1202A	70	--	N/A	--	98	12000	.1	

(1) Exceeds recommended Stress Ratio of 0.5
(2) Exceeds Recommended Stress Ratio of 0.6

(Sheet 6 of 8)

TABLE 5. INTEGRATED CIRCUIT STRESS

Date ____________

Unit Power Output & OSC Part of A6A3

Ref. Des.	Type	T_A (°C)	T_{JR} (°C)	T_{JA} (°C)	$\frac{T_{JA}}{T_{JR}}$	V_{PSR} (volts)	V_{PSA} (volts)	$\frac{V_{PSA}}{V_{PSR}}$	V_{inR} (volts)	V_{inA} (volts)	$\frac{V_{inA}}{V_{inR}}$	I_{LR} (mA)	I_{LA} (mA)	$\frac{I_{LA}}{I_{LR}}$	Notes
U1B02	3235747														
A		70	175	70	.4	16.5	15.75	.95(1)	N/A	--	--	--	2-CMOS	OK	4001
B		70	175	70	.4	16.5	15.75	.95(1)	N/A	--	--	--	1-100K	OK	4001
U2B02	3235769	70	175	70	.4	16.5	15.75	.95(1)	N/A	--	--	--	2-CMOS	OK	4047

(1) Nominal Voltage Rating is 15.0V

(Sheet 7 of 8)

TABLE 5 . MAGNETIC STRESS Date ________

Unit Power Output & OSC Part of A6A3

									$T_A = 70°C$		
Ref. Des.	Type	P_{rated} (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	V_{rated} (volts)	V_{actual} (volts)	$\frac{V_{actual}}{V_{rated}}$	I_{rated} (mA)	I_{actual} (mA)	$\frac{I_{actual}}{I_{rated}}$	
K1	2557519							5000	88	.1	Contacts 7-4
								5000	1630	.33	Contacts 1-5
					32	32	1				Vcoil-Cont.

(Sheet 8 of 8)

TABLE 6. SEMICONDUCTOR STRESS

Date ______

Unit 4.8KHZ OSC A6A1A1A2

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q1	TX2N2222A	70	350	6.3	.1	60	31	.52	$V_X = V_{CB}$
Q2	TX2N2905A	70	450	8.0	.1	60	31	.52	$V_X = V_{CE}$
Q3	TX2N4858	70	250	1	.1	40	1	.1	$V_X = V_{DS}$
Q9 A6A1A1	3235717	70	48W	1W	.1	100	45	.45	$V_X = V_{CE}$
Q10 A6A1A1	3235704	70	48W	1W	.1	100	45	.45	$V_X = V_{CE}$

(Sheet 1 of 9)

TABLE 6. RESISTOR STRESS

Date ______

Unit 4.8KHZ OSC A6A1A1A2

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R1	2540942-17	28K	1	70	300	~0	.1	
R2	RNC60H	3.01K	1	70	125	~0	.1	
R3	RNC60H	511	1	70	125	~0	.1	
R4	RLR07	470	2	70	250	~0	.1	
R5	RLR07	330	2	70	250	30	.12	
R6	2540942-1	10K	1	70	300	8	.1	
R7	RLR07	330	2	70	250	18	.1	
R8	RLR20	390	2	70	250	10.6	.1	
R9	RLR20	390	2	70	250	10.6	.1	
R10	2540942-21	33.2K	1	70	300	~0	.1	
R11	RLR07	390	1	70	250	72	.29	

(Sheet 2 of 9)

TABLE 6. RESISTOR STRESS

Date ______

Unit 4.8KHZ OSC A6A1A1A2

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R12	RNC60	5.11K	1	70	125	43	.34	
R13	RLR07	150K	2	70	250	~0	.1	
R14	RLR07	100K	2	70	250	2.4	.1	
R15	RNC60	5.11K	1	70	125	43	.34	
R16	RNC60	562	1	70	125	25	.2	
R17	RNC60	475	1	70	125	25	.2	
R18	RLR32	18K	2	70	1000	~0	.1	
R19	RLR32	18K	2	70	1000	~0	.1	
R20	RLR07	47K	2	70	250	18	.1	
R21	RLR07	620	2	70	250	57	.23	
R22	RLR07	620	2	70	250	57	.23	
R23	RLR07	1K	2	70	250	91	.36	

(Sheet 3 of 9)

TABLE 6. RESISTOR STRESS

Date ____________

Unit 4-8KHZ OSC A6A1A1A2

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R24	RLR07	1K	2	70	250	91	.36	
R25	RLR07	100K	2	70	250	~0	.1	
R26	254-0942-23	4.02K	1	70	300	~0	.1	
R27	RLR07	150K	2	70	250	~0	.1	
R10 A6A1A1	RWR89	1	1	70	2460	28	.1	
R11 A6A1A1	RWR89	1	1	70	2460	28	.1	

(Sheet 4 of 9)

TABLE 6. CAPACITOR STRESS

Date ______

Unit 4.8 KHZ OSC A6A1A1A2

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C1	M39014/2	70	100	45	.45	Ceramic
C2	M39006/9	70	75	45	.6	Tantalum(Pol., Slug)
C3	CM20FD	70	500	~0	.1	MICA
C4	CM20FD	70	500	~0	.1	MICA
C5	M39014/1	70	100	45	.45	Ceramic
C6	M39014/1	70	50	22	.44	Ceramic
C7	M39014/2	70	50	7	.14	Ceramic
C8	M39014/1	70	200	24	.12	Ceramic
C9	M39003/1	70	50 Peak .12 RMS	11.4 .58 RMS	.23 4.83 (1)	Tantalum (Pol., Solid) CSRB Ripple
C10	M39003/1	70	50 Peak .11 RMS	11.4 .58 RMS	.23 4.83 (1)	Tantalum (Pol., Solid) CSRB Ripple

(1) Exceeds Device Ripple Rating

(Sheet 5 of 9)

TABLE 6. CAPACITOR STRESS

Date ____________

Unit 4.8KHZ OSC A6A1A1A2

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C11	M39014/2	70	100	15	.15	Ceramic
C12	CM15FD	70	500	~0	.1	Mica
C13	M39014/2	70	100	15	.15	Ceramic
C15	M39014/1	70	200	~0	.1	Ceramic
C16	M39014/1	70	200	5.3	.1	Ceramic

(Sheet 6 of 9)

TABLE 6 . SEMICONDUCTOR STRESS - DIODES Date ______

Unit 4.8~~KHZ~~ OSC A6A1A1A2

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
CR1	TXIN914	70	.2	175	.1	.2	52.5	.1	
CR2	TXIN914	70	~ 0	175	.1	.2	52.5	.1	
CR3	TXIN5417	70	NA	--	NA	231	2600	.1	
CR4	TXIN5417	70	NA	--	NA	231	2600	.1	
CR5	TXIN914	70	~ 0	175	.1	~ 0	52.5	.1	
VR1	TXIN3045B	70	154	700	.22	NA	--	NA	
VR2	TXIN3045B	70	154	700	.22	NA	--	NA	
VR3	TXIN941B	70	74	350	.21	.6	32	.1	
VR4	TXIN941B	70	74	350	.21	.6	32	.1	

(Sheet 7 of 9)

TABLE 6 . INTEGRATED CIRCUIT STRESS Date ______

Unit 4.8KHZ OSC A6A1A1A2

Ref. Des.	Type	T_A (°C)	T_{JR} (°C)	T_{JA} (°C)	$\frac{T_{JA}}{T_{JR}}$	V_{PSR} (volts)	V_{PSA} (volts)	$\frac{V_{PSA}}{V_{PSR}}$	V_{inR} (volts)	V_{inA} (volts)	$\frac{V_{inA}}{V_{inR}}$	I_{LR} (mA)	I_{LA} (mA)	$\frac{I_{LA}}{I_{LR}}$	Notes
ARI	2557368 (RM4131)	70	125	NA	NA	22	15.2	.69	--	NA	--	--	NA	--	
		P_R (mW)	P_A (mW)	P_A/P_R											
		500	207	.41											

(Sheet 8 of 9)

TABLE 6. MAGNETIC STRESS Date ________

Unit 4.8KHZ OSC A6A1A1A2

Ref. Des.	Type	P_{rated} (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	V_{rated} (volts)	V_{actual} (volts)	$\frac{V_{actual}}{V_{rated}}$	I_{rated} (uA)	$T_A = 70°C$ I_{actual} (uA)	$T_A = 70°C$ $\frac{I_{actual}}{I_{rated}}$
T1	2047423[(1)]		790							
L1	2047352[(1)]									

(1) Device ratings, drawing not available.

(Sheet 9 of 9)

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TABLE 7. SEMICONDUCTOR STRESS

Date ________

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q1	TX2N4858	70	250	2.3	.1	40	15	.38	$V_X = V_{DS}$
Q2	TX2N5116	70	370	2	.1	30	15	.5	$V_X = V_{DS}$
Q3	TX2N2222A	70	350	6	.1	60	30	.5	$V_X = V_{CD}$
Q4	TX2N2905A	70	450	8	.1	60	30	.5	$V_X = V_{CE}$
Q5	TX2N4858	70	250	1	.1	40	1	.1	$V_X = V_{DS}$
Q7 A6A1A1	3235717	70	48	1	.1	100	45	.45	$V_X = V_{CE}$
Q8 A6A1A1	3235704	70	48	1	.1	100	45	.45	$V_X = V_{CE}$

(Sheet 1 of 9)

TABLE 7. RESISTOR STRESS

Date ____________

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R1	RLR07	15K	2	70	250	38	.15	
R2	RLR07	4.7K	2	70	250	12	.1	
R3	RLR07	15K	2	70	250	38	.15	
R4	RLR07	4.7K	2	70	250	12	.1	
R5	RLR07	12K	2	70	250	81	.32	
R6	2540942-2	110K	1	70	300	~0	.1	
R7	RNC60	20K	1	70	125	~0	.1	
R8	RLR07	12K	2	70	250	81	.32	
R9	RNC60	511	1	70	125	~0	.1	
R10	RLR07	1K	2	70	250	~0	.1	
R11	RLR07	330	2	70	250	67	.27	
R12	2540942-5	130K	1	70	300	~0	.1	

(Sheet 2 of 9)

TABLE 7. RESISTOR STRESS Date ________

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R13	RLR07	390	2	70	250	72	.29	
R14	2540942-1	10K	1	70	300	~0	.1	
R15	RLR07	330	2	70	250	67	.27	
R16	RLR07	270K	2	70	250	~0	.1	
R17	RNC60H	1K	1	70	125	7	.1	
R18	RNC60H	5.11K	1	70	125	33	.26	
R19	RNC60H	5.11K	1	70	125	14	.1	
R20	RNC60H	9.53K	1	70	125	63	.5	
R21	RLR07	47K	2	70	250	9	.1	
R22	RLR07	620	2	70	250	55	.22	
R23	RLR07	620	2	70	250	55	.22	
R24	RLR07	100K	2	70	250	~0	.1	
R25	RLR07	1K	2	70	250	92	.37	

(Sheet 3 of 9)

TABLE 7. RESISTOR STRESS Date ________

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R26	RLR07	1K	2	70	250	92	.37	
R27	2540942-23	4.02K	1	70	300	~0	.1	
R28	RLR07	150K	2	70	250	~0	.1	
R29	RLR07	100K	2	70	250	5	.1	
R30	RLR07	10K	2	70	250	~0	.1	
R8 A6A1A1	RWR89	1	1	70	2460	55	.1	
R9 A6A1A1	RWR89	1	1	70	2460	55	.1	

(Sheet 4 of 9)

TABLE 7. CAPACITOR STRESS

Date ______

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C1	M39006/9	70	75	45	.6	Tantalum (Pol., Slug)
C2	M39014/2	70	100	45	.45	Ceramic
C3	CM20F	70	300	45	.15	Mica
C4	CM20F	70	300	45	.15	Mica
C5	M39014/1	70	200	45	.23	Ceramic
C6	M39014/2	70	50	28	.56	Ceramic
C7	M39014/2	70	200	22	.11	Ceramic
C8	M39014/2	70	100	28	.28	Ceramic
C9	CM15F	70	500	45	.1	Mica

(Sheet 5 of 9)

TABLE 7. CAPACITOR STRESS Date ______

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C10	M39006/1	70	75 DC 2.57 RMS	23.5V 2.9 RMS	.31 1.13 (1)	Tantalum (Pol., Etched Foil) Ripple
C11	M39006/1	70	75 DC 2.57 RMS	23.5V 2.9 RMS	.31 1.13 (1)	Tantalum (Pol., Etched Foil) Ripple
C13	M39014/1	70	200	45	.23	Ceramic
C14	M39014/1	70	200	45	.23	Ceramic

(1) Device is Over Stressed

(Sheet 6 of 9)

TABLE 7 . SEMICONDUCTOR STRESS - DIODES   Date ________

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR1	TXIN5534B	70	35	347	.1	--	N/A	--	
VR2	TXIN5534B	70	35	347	.1	--	N/A	--	
VR3	TXIN5534B	70	38	347	.1	--	N/A	--	
VR4	TXIN5534B	70	38	347	.1	--	N/A	--	
CR1	TXIN914	70	3	175	.1	2.3	52.5	.1	
CR2	TXIN5417	70	N/A	--	N/A	328	2600	.13	
CR3	TXIN5417	70	N/A	--	N/A	328	2600	.13	
CR4	TXIN914	70	~0	175	.1	.23	52.5	.1	
CR5	TXIN914	70	~0	175	.1	.23	52.5	.1	

(Sheet 7 of 9)

TABLE 7. MAGNETIC STRESS

Date ______

Unit 400 HZ OSC A6A1A1A1

Ref. Des.	Type	P_{rated} (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	V_{rated} (volts)	V_{actual} (volts)	$\frac{V_{actual}}{V_{rated}}$	I_{rated} (uA)	T_A = 70°C I_{actual} (uA)	T_A = 70°C $\frac{I_{actual}}{I_{rated}}$
T1	2557351	19,000	6,000	.32						

(Sheet 8 of 9)

TABLE 7. INTEGRATED CIRCUIT STRESS   Date ________

Unit 400HZ OSC A6A1A1A1

Ref. Des.	Type	T_A (°C)	T_{JR} (°C)	T_{JA} (°C)	$\frac{T_{JA}}{T_{JR}}$	V_{PSR} (volts)	V_{PSA} (volts)	$\frac{V_{PSA}}{V_{PSR}}$	V_{inR} (volts)	V_{inA} (volts)	$\frac{V_{inA}}{V_{inR}}$	I_{LR} (mA)	I_{LA} (mA)	$\frac{I_{LA}}{I_{LR}}$	Notes
AR1	2557368 (RM4131)	70	125	NA	NA	22	15.2	.69	--	NA	--	--	NA	--	
			P_R (mW)	P_A (mW)	P_A/P_R										
			500	207	.41										

(Sheet 9 of 9)

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APPENDIX B

DAR 77-008

DATA ANALYSIS REPORT

DESIGN ASSURANCE
NEARTIP
RELIABILITY•MAINTAINABILITY

ARINC RESEARCH CORPORATION

NUMBER	77-003 Rev. 1
DATE	7 March 1977
CC	M. O. Heinrich R. Matthews R. Bowen

TO	REFERENCE	
S. Vaihora	F77-002	

Circuit power stresses, failures and testing of R4 (A2) in the +15 volt power supply (A6A2) is the subject of this report.

Part Number: 2540940

Manufacturer: Dale

REQUESTED BY	TELEPHONE NO./EXTENSION	DATE
R. Matthews	(714) 225-2528	

DATA ANALYSIS SUMMARY

ARINC recommends the power stress ratio on R4 (A2) in the +15 volt power supply be lowered to an acceptable level.

Worst case power stress ratio of the resistor is .83 during steady state operation (calculated) and 9.0 during short circuit conditions (measured).

Excessive current is the reason two resistors failed. This could be caused by a short circuit to +40 volts on R4 or an inoperative over current protection circuit.

Testing of two sample resistors showed that during a short circuit system condition the solder on the resistor case will melt when the resistor current is held at ≃ 7 amps for four minutes and the resistive wire could burn open when held at ≃ 8.5 amps for 20 minutes.

PREPARED BY	APPROVED	DATE
R. C. Gellner	J. R. Gliessman	3/7/77

PAGE OF

I. INTRODUCTION

A. Purpose of the Report

The purpose of this report is to analyze the failures and overstress conditions of R4 (A2) in the NEARTIP +15 volt power supply (A6A2).

B. Method and Scope of the Report

This DAR reports on the failure of two resistors in the NEARTIP +15 volt power supplies and ARINC testing of two sample resistors. Failure report analysis, power supply circuit analysis, direct testing of Dale resistors, and microscopic examination of failed resistors were methods used to collect data for this report.

C. Basic Plan

As a basis for analyzing the resistor problem, the report examines in this order -- present circuit conditions of R4, description of past resistor failures and ARINC testing of resistor samples.

II. DESCRIPTION OF PRESENT RESISTOR CIRCUIT CONDITIONS

A. Power Stress During Steady State Operating Conditions

Presently, during steady state worst case operating conditions R4 has a power stress ratio of .85 when operating at a worst case circuit current level of 2.6 amps. The recommended power stress ratio is .4. A component is overstressed if the power stress ratio exceeds 1.0.

B. Power Stress During Short Circuit Operating Conditions

When the +15 volt power supply is in a short circuit protection mode, the worst case measured current is 8.6 amps. The resistor power stress ratio is 9.0.

Power stress of R4 is high during the normal steady state operating condition, and excessive during a short circuit mode of operation.

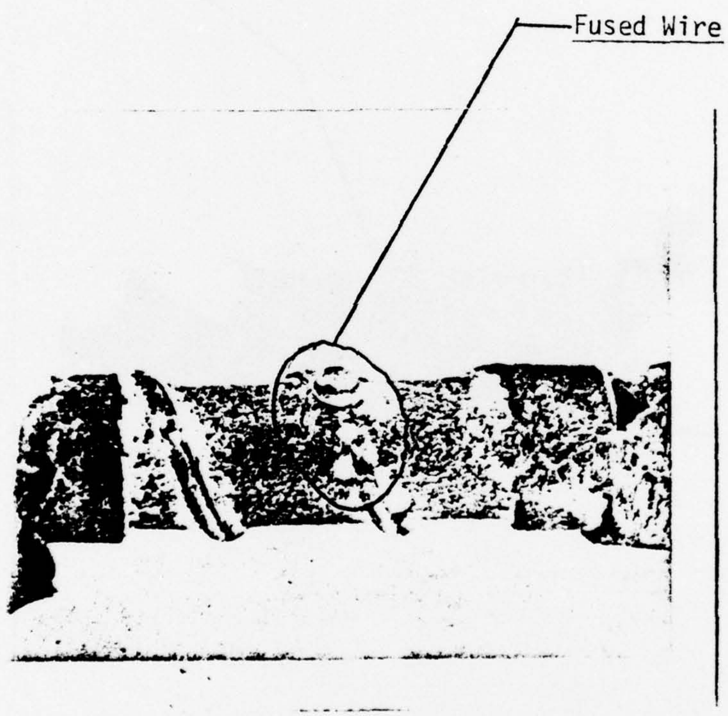
III. DESCRIPTION OF TWO DALE RESISTOR FAILURES

Two resistors have failed in the past 10 months, one during a sea run and one while the system was on a test set. Both of these components were manufactured by Dale Electronics.

A. June 1976 Failure (Failure Report #A1069)

In June 1976 R4 (A2) in the +15 volt power supply failed during a sea run. It was found to be open. The resistor's case showed no visible signs of stress. Replacing R4 in the supply was the only reported action required to repair the unit.

A clean break and no sign of a large burn area was found when this resistor was examined (Photograph 1). This break was probably due to short time interval current pulse that caused the resistor to fuse. Notice to the left of the break is a splattered piece of wire. That could happen with a quick fusing action.



PHOTOGRAPH 1

Resistor

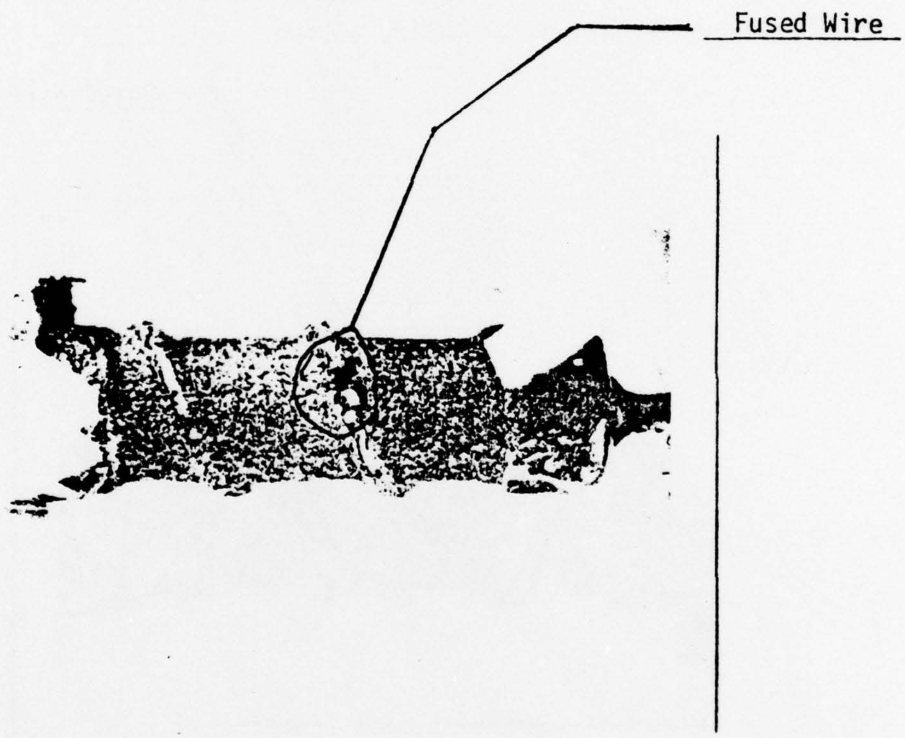
From June 1976 Failure

B. January 1977 Failure (Failure Report #A1142)

In January 1977 R4 in the +15 volt power supply failed during a test set operation. It was found to be open. The resistive case showed no visible signs of stress.

Replacing R4, Q1, and CR2 allowed the power supply to operate again. Information on the condition of Q1 and CR2 is not available.

A photograph of the failed Dale resistor (Photograph 2) shows a clean break and no sign of a large burn area. This method of break was probably due to a fusing action. A large current in a short period of time is necessary for a resistor of this type to fuse open. Under a microscope the beads of melted material are visible. The Dale representative stated, "the melted beads are an indication of a fusing action".



PHOTOGRAPH 2
Resistor

From January 1977 Failure

IV TESTING THE RESISTOR SAMPLES

To better understand the characteristics of this resistor, we tested two sample resistors at our laboratory in Santa Ana, California. One resistor was obtained from Bendix 35-Lot spares, and the other was obtained directly from Dale.

A. Brief Description of the Test Set Up

The test set up included three main pieces of test equipment. A variable power supply was used to generate different values of current. A thermocouple bridge allowed us to measure the case temperature of the resistor. During testing the digital voltmeter was used to accurately determine the value of resistor.

B. Dale Resistor Sample

Dale Company sent us a resistor sample to use for testing. The resistor was the same as the failed type.

During the test, with seven amps of current applied, solder on the case melted. With 8.5 amps of current applied to the resistor, after twenty minutes it burned open. 8.6 amps was the highest value of current we measured on the NEARTIP +15 volt power supply.

The current, temperature, voltage, and resistance measurements and also comments made during the test are listed in TABLE I. The power values in TABLE I were calculated from the equation

$$P = I^2R$$

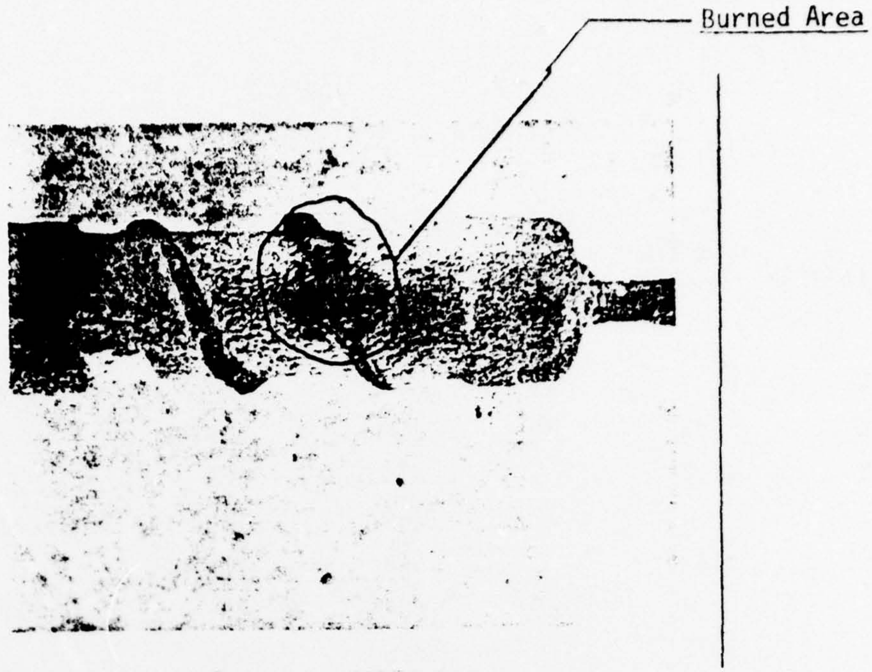
where I is the applied current and R is 0.15 ohm.

TABLE I

TEST DATA FOR THE DALE SAMPLE RESISTOR

I (AMPS)	POWER (WATTS CALC.)	TEMP (C°)	VOLTAGE (VOLTS)	RESISTANCE (OHMS)	COMMENTS
0	0	24	0		Base Line
1	.15	32			
3	1.35	96			
4	2.4	140			
5	3.75	160	.78	.16	Added Digital Voltmeter
6	5.4	202	.934	.16	
7	7.35	254	1.13	.16	Solder on Case Melts
7.5	8.4	290	1.23	.164	Solder on Case Completely melts
8	9.6		1.35	.167	Case turns red
8.5	10.84	≈370			After 20 minutes the Resistor burned open

The photograph of the sample Dale resistor (Photograph 3) shows a large burn spot where the wire opened up. Long exposure to a high temperature was the reason for this failure. Notice the wire again broke near the center of the resistor. Heat can flow away easier from the ends that it can from the middle of the wire. Therefore, the center is the hottest spot on the resistor and the most likely area for a break.



PHOTOGRAPH 3
DALE SAMPLE RESISTOR

C. Bendix Sample Resistor

Bendix Corporation gave us a resistor from 35-Lot spares to use for testing purposes. This resistor was also manufactured by Dale and was used mainly to determine how long it takes to melt solder on the resistor case. From 25°C, room temperature it took 4 minutes for the case temperature to reach 250°C and melt the solder. The applied current was 7 amps.

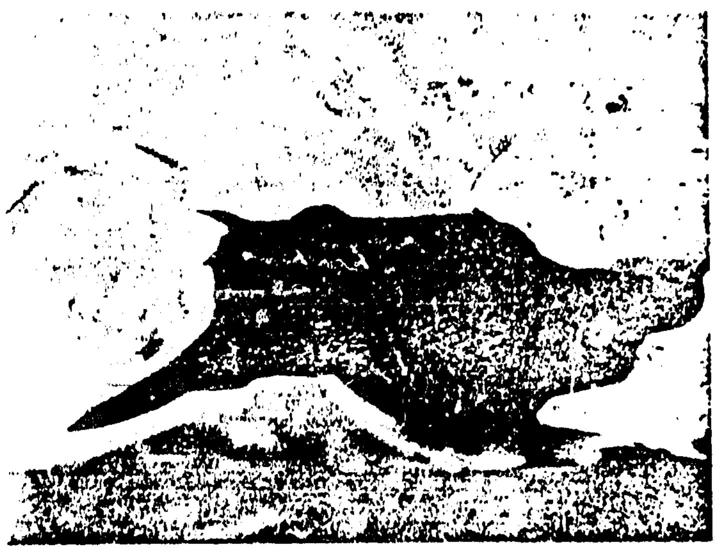
Complete data for the Bendix sample resistor is in Table 2.

TABLE 2

TEST DATA OF THE BENDIX SAMPLE RESISTOR

I (AMPS)	P (WATTS CALC.)	CASE TEMP. (C°)	V (VOLTS)	R (OHMS)	COMMENTS
0	0	24	0		Baseline, Room Temperature
1	.15	30	.152	.152	
3	1.35	--	.453	.152	
		77	.459	.153	Temperature stabilizes
4	2.4		.618	.155	
		114	.624	.156	Temperature stabilizes
5	3.75		.776	.155	
		157	.784	.157	
6	5.4		.938	.156	
		206	.946	.158	
6	5.4	28	.916	.153	Start heat transient test
6	5.4	180	.937	.156	2 minutes
6	5.4	201	.94	.157	5 minutes
6	5.4	204	.944	.157	10 minutes
Series of 20 On/Off Transients 6A Maximum Current					
6.5	6.34	233	1.02	.158	Continue original test
7.0	7.35	250	1.14	.163	4 minutes transient from 25°C to melting point of solder on case ends.
7.0	7.35	260	1.149	.164	Maximum temperature for 7 amps.

There is no visible damage to the resistor used for this test. (See Photograph 4) If the solder on the case ends had not melted, the resistor could still be used.



PHOTOGRAPH 4
BENDIX SAMPLE RESISTOR

7. CONCLUSION OF RESISTOR ANALYSIS

A. Failed Resistors

The June 1976 resistor failure was caused by a fusing action. A fusing process requires a large amount of current. Exact system circumstances are unknown. The physical appearance of the resistor was normal except for the broken resistive wire.

The January 1977 failure was also caused by a fusing action. The physical appearance of the resistor was normal except for the broken resistive wire.

B. Sample Resistors

Sample resistors were tested under worst case system conditions. The current used was the maximum short circuit current the +15 volt power supply can generate.

Testing and analysis of two sample resistors revealed the following information:

1. The solder on the ends of the case will melt with 7 amps of current applied for 4 minutes. Except for the melted solder on the case, the physical appearance will remain unchanged.

2. The resistor will burn open with 8.5 amps of current applied for 20 minutes. Melted solder on the case and a large burn area around the broken resistive wire are physical characteristics for this type of failure.

3. Resistance value of the resistor changed substantially only when it was about to burn open.

C. Failure Mode

Because of the marked difference in physical appearance between the two failed resistors and the two tested sample resistors we conclude that if the +15 volt power supply short circuit protection was operating, the resistors would not have failed in the manner that they did.

Some possible reasons the short circuit protection circuitry would not operate are:

1. A direct short from the +40 volt power supply to the Dale resistor would bypass the short circuit protection circuitry.

2. A failed component in the short circuit protection circuitry would allow enough current to flow in the resistor to fuse it open.

We conclude the failed fusing resistors operated as they were intended; that is, to protect the power supply from a prolonged excessive current demand. (i.e. in excess of 10 amps). The source of the excessive current was not determined.

D. <u>Resistor During System Operation</u>

We conclude the resistor worst case power stress level of .83 during steady state operating condition is too high. The recommended power stress ratio is .4.

Up to 8.5 amps can be generated by the 15 volt power supply during short circuit conditions. If the system is allowed to remain in this condition we conclude the following:

1. At 7 amps the resistor case solder will melt.

2. At 8.5 amps the resistor wire will burn open.

VI. RECOMMENDATIONS

Because power stress on the resistor during both short circuit and steady state operating conditions are too high, we recommend the stress levels be lowered to an acceptable value.

A method of lowering the steady state power stress level and greatly relieving the possibility of resistor burn out during short circuit conditions can be accomplished in two steps.

1. Change the power rating of the resistor from 1.5 to 2.5 watts. Dale Electronics informs us, the 2.5 watt resistor can be manufactured, and that the physical size will be close enough to the present size to allow the parts to be interchanged one for one. A steady state power stress ratio decrease from .83 to .5 will result from this change.

2. Remove CR2 from the +15 volt regulator assembly. Resistor short cicruit conditions will be improved by the amount shown in Table 3.

TABLE 3

RESISTOR STRESSES BEFORE AND AFTER THE RECOMMENDED CHANGES

	Rated Power (Watts)	Short Circuit Current (Amps)	Short Circuit Power (Watts)	Power Stress Ratio	Solder Melting Current (Amps)	Resistor Burn Open Current (Amps)
Original System	1.2	8.5	10.84	9.03	≃ 7	≃ 8.6
Recommended System	2.0	4.4	2.90	1.45	≃ 8	≃ 9.6

The resistor rated power capabilities in Table 3 are derated from room temperature to 70°C. Resistor, R4 in the recommended system is increased to a 2.5 watt power rating at room temperature.

The recommended changes will greatly reduce the possibility of a failure in the power supply due to a short circuit developed somewhere else in the NEARTIP system.

More research, testing and engineering must be conducted before this change can be made. The following are some of the questions that must be answered.

1. Will the lower current capability impact the NEARTIP system either now or in the future?

2. How will the power supply current capability change with temperatures?

3. Will the new resistor meet NEARTIP reliability requirements?

4. Can CR2 be safely removed from the system?

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APPENDIX C

DAR 77-009

DATA ANALYSIS REPORT

DESIGN ASSURANCE
NEARTIP
RELIABILITY•MAINTAINABILITY

ARINC RESEARCH CORPORATION

NUMBER	77-009
DATE	8 March 1977
CC	M. O. Heinrich R. Matthews

TO	REFERENCE
S. Valihora	Control Group Power Circuits Stress Analysis

Possible replacement of C1 in the +15 volt power supply (A6A2) to minimize the effects of a reverse voltage spike applied to the capacitor.

REQUESTED BY	TELEPHONE NO./EXTENSION	DATE
R. Matthews	(714) 225-2528	

DATA ANALYSIS SUMMARY

An aluminum electrolytic was the only capacitor type that could be found to replace the sintered slug tantalum capacitor C1 in the +15 volt power supply. Shape factor and electrical characteristics were key elements in the search. Aluminum capacitors were found to have possible problems of their own. These areas are outlined below:

- MIL-STD-198C states that provisions should be made to protect surrounding parts due to explosion potential.

- Maximum ripple frequency is 10 KHz.

Because of possible problems that introduction of an aluminum capacitor may introduce, we believe that elimination of the negative voltage across the capacitor would be a more acceptable solution.

MIL-Standard 198C recommends a maximum ripple frequency of 10 KHz for a sintered slug tantalum capacitor. The 20 KHz ripple frequency that is now

Continued

PREPARED BY	APPROVED	DATE
R. C. Gellner	J. R. Gliessman	3/8/77

present has a system measured amplitude of 20 millivolts. However, this low level of ripple voltage should not unduly stress a sintered slug tantalum capacitor.